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RESEARCH ARTICLE

Movement distances for four small mammals in two Atlantic forests fragments, Southern Brazil

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Abstract

Animal movement has an important role in individual performance, species reproduction, population demography, and conservation, especially in fragmented landscapes. The distance moved by an individual may vary depending on individual needs, such as the search for food resources and sexual partners. Here we investigated which factors affect the distances between successive captures (hereafter DSC) for *Akodon montensis*, *Oligoryzomys nigripes*, *Sooretamys angouya*, and *Didelphis albiventris*. This study was conducted from April 2015 to October 2016 in two fragments in the south of Atlantic Forest biome through capture, mark and recapture technique. DSC was analyzed using Generalized Linear Models with Poisson distribution where the independent variables were sex, whether the animal was active or not in terms of reproduction, body weight, and climatic season. The mean DSC was greater for *D. albiventris* (44.6 ± 28.8 m), followed by *S. angouya* (31.9 ± 25.7 m), *O. nigripes* (25.8 ± 22.5 m) and *A. montensis* (18.9 ± 22.0 m). Males of all species moved larger DSC than females. Considering the rodents, reproductive animals also moved larger DSC than non-reproductive animals. Sex may have masked the effect of body weight, as males tend to be larger than females. Climatic effects were tested for *A. montensis* and *O. nigripes*, however, with diverse effects.

Keywords

Akodon montensis, *Didelphis albiventris*, distances between successive captures, *Oligoryzomys nigripes*, *Sooretamys angouya*

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PENSOFT

Introduction

Animal movement patterns and distances vary depending on individual needs. For instance, climatic seasons will affect food resources (Naxara et al. 2009) and during food shortage periods, animals might have to move longer distances to find food (Winker et al. 1995; Loretto and Vieira 2005); and the same happens for animals with bigger corporal size, that need more food resources (Lima et al. 2016). It will also affect sex and reproduction conditions, which in turn can influence individual movement, as during reproduction males tend to undertake more movements, attempting to mate with the largest number of females (Cáceres 2003; Loretto and Vieira 2005; Lima et al. 2016). Animal movement plays a major role also on species conservation, as it is crucial to understand the rate and distance of movements to predict how isolated each species will be in fragmented landscapes (Pires et al. 2002).

There is a great variety of methodological approaches to study animal movement, ranging from the most sophisticated and data demanding methods, such as the kernel estimates of home range (Fleming et al. 2015), to more simplistic methods, such as the distances moved between successive captures (DSC; for more explanation on this method see Püttker et al. 2006 and Püttker et al. 2012). The home range estimate methods are especially useful to accurately describe home range area, shape, and overlap between individuals (Leite et al. 2016). However, these methods require a large number of locations per individual to provide reliable estimates (Boyle et al. 2009). On the other hand, the more simplistic methods, such as the DSC, are easy to calculate and can be used even for individuals with only two captures in the same trapping season. This increases sample size and allows for multiple comparisons among individuals, as well as comparisons between sex, seasons, and environments (Püttker et al. 2006; Lima et al. 2016). Moreover, DSC is robustly correlated to home range estimates (Püttker et al. 2012).

Our goal in this study was to investigate which factors are related to animal movement for four species of small mammals, in fragments of Atlantic Forest, southern Brazil. We hypothesized that differences among species are mainly related to body size and that within species (i) males would move more than females; (ii) reproductive animals would move more than non-reproductive animals; (iii) bigger animals would move more than smaller animals; and, that (iv) animals would move more during winter, due to reduced food availability.

Material and methods

The study was carried out from April 2015 to October 2016, with field sampling in each climatic season, in two Atlantic Forest fragments (Fragment 1: 28°08'38"S, 54°45'36"W, 30 ha; Fragment 2: 28°07'33"S, 54°44'57"W, 20 ha) in Cerro Largo municipality, state of Rio Grande do Sul, Brazil (Fig. 1). These fragments are covered by deciduous forest located in an ecotone within the grassland dominated Pampa biome. These fragments have at least 62 arboreal species from 28 families; Fabaceae had the greater species richness (Souza et al. 2020). Fragments are situated in pri-

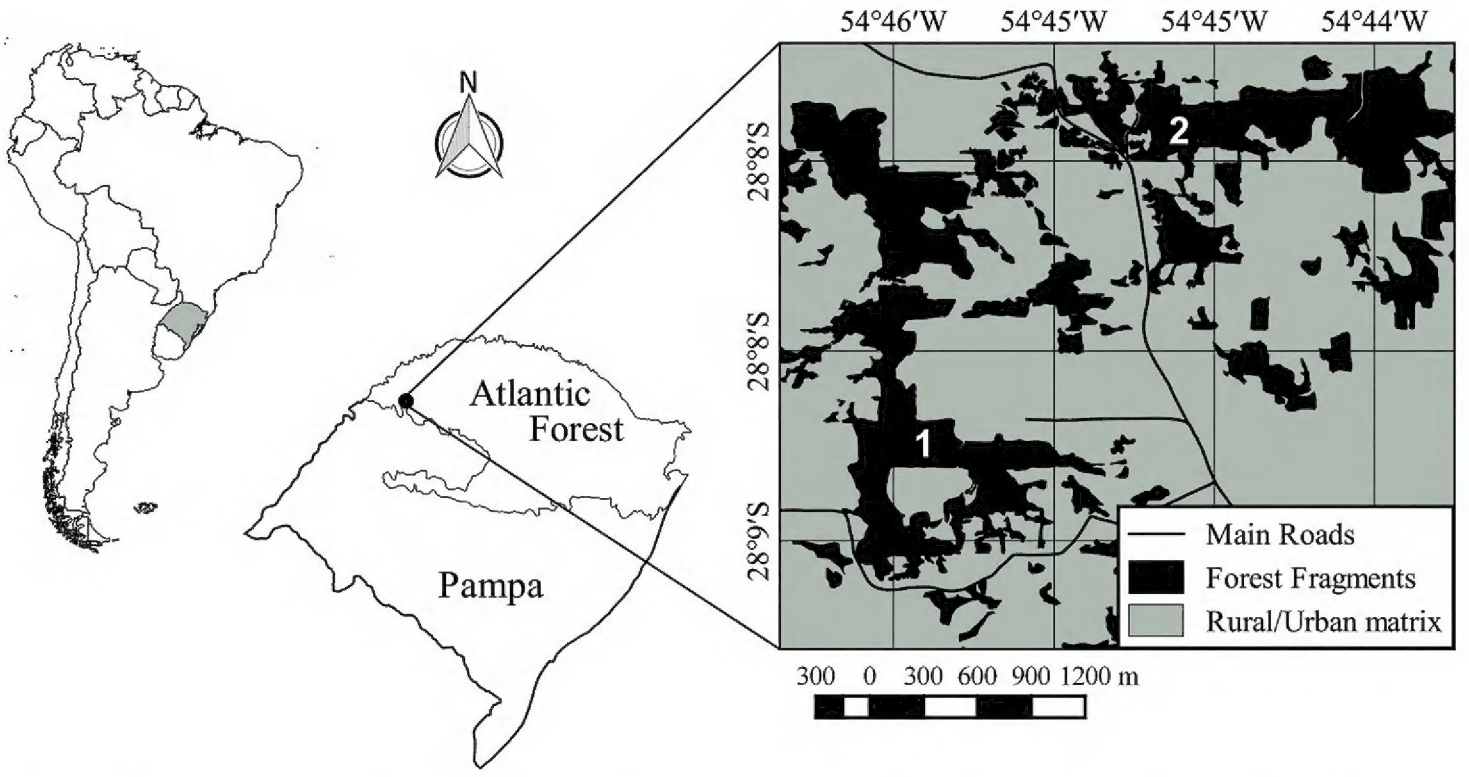

Figure 1. Location of the study area in South America and Rio Grande do Sul, Brazil. Atlantic Forest and Pampa biome extents are shown in the detail of the state of Rio Grande do Sul. Numbers 1 and 2 indicate the studied fragments.

vate lands and the surrounded matrix has both urban and agricultural elements. The local climate is subtropical, Cfa type (Peel et al. 2007). Mean annual rainfall is 1800 mm; the mean temperatures range from 20 °C to 30 °C in the hottest months, December to February, and from 10 °C to 20 °C in the coldest months, June to August (Kuinchtner and Buriol 2001).

Small mammals were sampled, from Fall 2015 to Spring 2016, including seven sampling seasons. Each season had 10 sampling nights in each area. We used Sherman (31×10×08 cm) and Tomahawk (45×17×17 cm) live-traps, distributed in three 120 m long transects with seven trapping stations, distant 20 m from each other, in each sampled area. Transects were 20 m apart from each other and at least 25 m apart from the edge. In each of the trapping stations two live-traps were randomly placed, one in the ground and one in the understory (approximately at 1.5 m height), totaling 42 live-traps in each area (Fragment 1 with a total sampling effort of 2380 trap-nights, and Fragment 2 with 2940 trap-nights). Each trap was baited with a mixture of peanut butter, banana, corn flour, sardine, and cod-liver oil. Captured individuals received a numbered ear tag and were released in the same trapping station. However, some individuals were deposited at the Universidade Luterana do Brasil, Museu de Ciências Naturais, Laboratório de Sistemática de Mamíferos (numbers 4404 to 4435) as voucher specimens. We collected tissue samples (ear plug) of each individual in order to confirm morphological identification of voucher specimens. This tissue was used for DNA extraction, amplification through polymerase chain reaction and sequencing of a fragment of the cytochrome b mitochondrial gene. Sequences were blasted both in the public NCBI (Genbank) and in a regional database (Nature Data in prep).

We analyzed the DSC for the four most abundant species, *Akodon montensis* Thomas, 1913, *Oligoryzomys nigripes* (Olfers, 1818), *Sooretamys angouya* (Fis-

Table 1. Variables included as predictors for animal movement for each species.

Species	#	Sex	Reproduction	Body weight	Climatic season
Akodon montensis	118	Included	Included	Included	Included
Oligoryzomys nigripes	33	Included	Included	Included	Included
Sooretamys angouya	30	Included	Included	Included	Not included*
Didelphis albiventris	22	Included	Not included**	Included	Not included*

= sample size. *Most captures occurred during one of the climatic seasons. **Only two individuals were reproductive.

cher, 1814), and *Didelphis albiventris* Lund, 1840. We recorded the specific position of each trapping station, so, when an individual was recaptured (within the same sampling season), we could measure the minimum distance traveled between these two successive captures, the DSC. Considering the high number of zeros on the dependent variable, the DSC (an animal recaptured on the same trapping station), we analyzed this dataset using Generalized Linear Models with Poisson distribution. First, we tested if DSC varies among species, using species identification as an independent variable. When analyzing which factors influence animal movement within species, the independent variables were (i) sex, (ii) whether the animal was active or not in terms of reproduction (scrotal testes for males, evidence of lactation or perforated vagina for females), (iii) body weight, and (iv) climatic season. However, due to our dataset characteristics, not all independent variables were tested for all species (Table 1). Our models did not include interaction among the dependent variables because we would need higher sample sizes of DSC for each species to estimate a higher number of parameters. Starting with the full model for each species, we fitted a backward model selection where the deletion of each variable is tested using AIC value (Burnham and Anderson 2002). We present all models with Δ AIC smaller than two. All analyses were performed in R environment (R Core Team 2019). This study was authorized by Brazilian Institute of Environment and Natural Resources (46947-2) and UFFS Animal Ethics Committee (009/CEUA/UFFS/2015).

Results and discussion

We had 118 DSC values for *A. montensis* (mean ± standard deviation: 18.9 ± 22.0 m; ranging from 0–130 m); 33 for *O. nigripes* (25.8 ± 22.5 m; 0–100 m); 30 for *S. angouya* (31.9 ± 25.7 m; 0–103 m) and 22 for *D. albiventris* (44.6 ± 28.8 m; 20–123 m). The GLM analysis confirmed the differences among species (AIC = 5556.2; AIC null model = 6065.7). This result mostly confirms our hypothesis regarding differences among species, since *D. albiventris* has the greatest body size (mean ± standard deviation: 522 ± 596 g) followed by *S. angouya* (108 ± 12 g). Considering the other two rodents, even though *O. nigripes* (27 ± 8 g), the smaller species, had greater DSC than *A. montensis* (35 ± 8 g), the body size difference among these species is very small and it is probably second in place regarding this DSC difference.

According to the best model for *A. montensis*, males had greater DSC; reproductive animals had greater DSC, and DSC was greater during summer, spring, and au-

tumn when compared to winter. The second best model for *A. montensis* considered also that heavier animals had greater DSC (Fig. 2A). The best model for *O. nigripes* considered that males had greater DSC; reproductive animals had greater DSC and DSC was smaller during spring when compared to winter. The second best model for *O. nigripes* considered also that heavier animals had smaller DSC (Fig. 2B). For *S. angouya* the best model indicated that males had greater DSC; reproductive animals had greater DSC and heavier animals had greater DSC (Fig. 2C). For *D. albiventris* the best model indicated that heavier animals had smaller DSC and the second best model included this negative effect but also indicated that males had greater DSC (Fig. 2D).

The DSC found here presented similar values to previous studies for *A. montensis* and *O. nigripes*. For *A. montensis*, in São Paulo state, the mean DSC varied between 19.54 m (Püttker et al. 2006) and 31.1 m (Püttker et al. 2012). For *O. nigripes*, mean DSC values of 31.81 m for males and 18.04 m for females (Püttker et al. 2006) were previously found. To the best of our knowledge, this is the first study presenting DSC values for *S. angouya*. Lastly, regarding the marsupial species *D. albiventris*, the values presented here are consistently smaller than previously recorded. In Pernambuco state, using radio-tracking devices, the mean daily distance moved for two males of *D. albiventris* was 177 and 424 m per night (Aléssio 2004). For *D. aurita*, the DSC values ranged from 0 to 300 m in coastal shrubland (Gentile and Cerqueira 1995) and from 445 to 1200 m in a fragmented landscape (Pires et al. 2002), both studies at Rio de Janeiro state. This divergence between our values and the literature for *D. albiventris* is probably related to our sampling area. The maximum distance

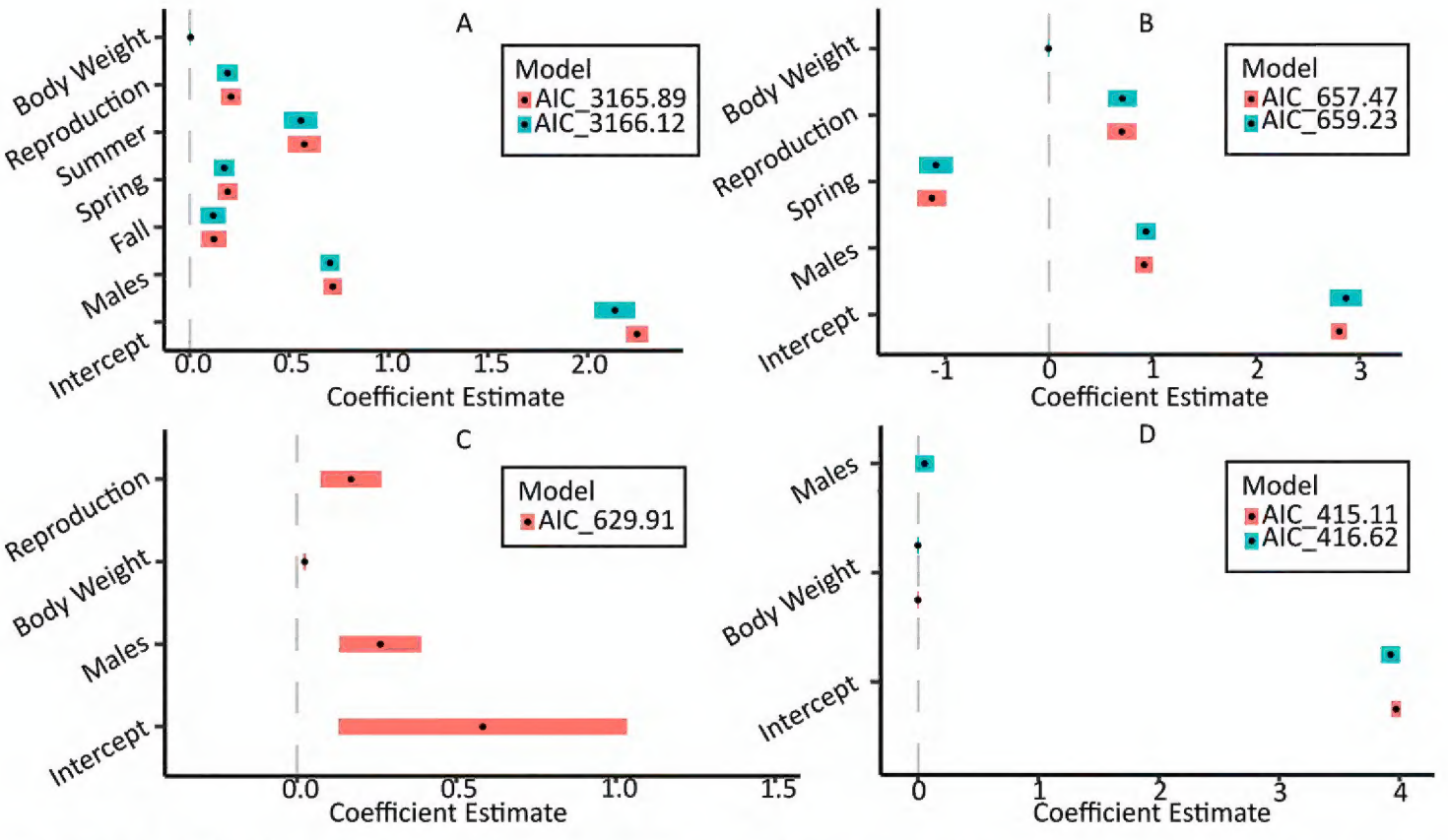

Figure 2. Variables coefficient and their confidence interval to explain DSC. All models with Δ AICc < 2 were considered to explain DSC variation for *Akodon montensis* (**A**), *Oligoryzomys nigripes* (**B**), *Sooretamys angouya* (**C**) and *Didelphis albiventris* (**D**).

among our trapping stations was 130 m, which seems suitable to capture most of the daily movements for our rodent species, but it is rather small to capture daily movements for *D. albiventris*, an animal with greater body size than the studied rodents and consequently that performs longer distances movements.

For the three analyzed rodents, males moved greater distances than females and reproductive individuals moved greater distances than non-reproductive individuals. Considering the correspondence between DSC and individuals' home range (Püttker et al. 2012), the sex differences might indicate a promiscuous mating system for these species, where males' larger home ranges would include more than one female home range, maximizing access to fertile females. On the other hand, females' smaller home ranges could indicate territorial behavior related to nest protection or food resource defense (Ostfeld 1990; Lima et al. 2016).

Larger animals demand more resources, so they need to explore larger areas to find them (Harestad and Bunnel 1979). This association was mostly confirmed among species, however, within species this effect was not clear. For *A. montensis* and *S. angouya*, heavier animals had greater DSC, but the opposite was found for *O. nigripes* and *D. albiventris*. However, it is very likely, at least for the rodent species, that the effect of sex may have masked the real effect of body weight, as males were larger than females for all rodent species (*A. montensis* mean male weight 36.9 g × mean female weight 32.9 g; *O. nigripes* 31.2 × 20.7 g; *S. angouya* 111.7 × 97.5 g). Further studies, with greater sample size, should include interaction between these variables to test whether there is an effect of body weight apart from the effect of sex on species movement, as it was already demonstrated to other rodent species in the Atlantic Forest (Lima et al. 2016).

Regarding the effect of climatic seasons on small mammals' movements, we discovered diverse impacts on the two analyzed rodents, *A. montensis* and *O. nigripes*, and we believe that further investigations are needed regarding this issue in the south of the Atlantic Forest. Most of the Atlantic Forest biome presents moderate temperature variation among seasons, but great variation in precipitation, described as dry and wet seasons. Usually, most small mammals increase their reproduction rates in the wet season, where there are more food resources, and change their movement behavior according to this reproduction event (Loretto and Vieira 2005; Lima et al. 2016). However, in our study area, even with similar vegetation and small mammal species composition, there is no dry season and there is a significant temperature variation during the year (Kuinchtner and Buriol 2001); it is very likely that the food availability for these species varies in a different way, driving diversely the climatic effects on reproduction and movement behavior.

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